



## METHOD OF PRODUCING HOMOGENEOUS GAS MIXTURES

### BACKGROUND OF THE INVENTION

**[0001]** The invention relates to a method for producing substantially homogeneous, compressed gas mixtures which contain perfluorinated and/or partially fluorinated hydrocarbons, and to a mixing station, in particular a mobile one, usable therein.

**[0002]** In principle, it is possible to convert gases which are separately present into a homogeneous gas mixture simply, by transferring the gases into a container and waiting for a sufficiently long time until a correspondingly homogeneous gas mixture has been produced by diffusion. Since however extremely long periods of time are required for this, such a method cannot be used industrially. Of course, mixing is also observed if gas streams are introduced into a stationary mixer and/or a common line. However, the mixing is not always so thorough that the mixtures obtained can be regarded as "homogeneous", in particular when it is desired to mix together gases having a high difference in density, for example those which contain perfluorinated and/or partially fluorinated hydrocarbons. Such gas mixtures can be used, for example, as insulating gas for current-carrying underground cables or in gas-insulated circuits. A particular problem in this case is that the gas mixtures (which are required in very large quantities) expediently need to be produced on the spot. For if it were desired to use gas mixtures prefabricated in a factory, these would have to be transported in gas cylinders under high pressure, in order to keep the transportation costs as low as possible; however, this is not possible, since then the content of fluorinated hydrocarbons condenses out and corresponding demixing would occur.

## SUMMARY OF THE INVENTION

**[0003]** It is an object of the present invention to provide a method with which homogeneous compressed gas mixtures with fluorinated hydrocarbons and other gases with a high difference in density can be produced.

**[0004]** Another object of the present invention is to provide a mixing station which can be used for this purpose, in particular a mobile mixing station which can be used for this purpose.

**[0005]** A further object is to provide a mixing station which is protected from dirt and the effects of the weather.

**[0006]** These and other objects are achieved in accordance with the present invention by providing a method for producing a homogeneous compressed gas mixture, said method comprising premixing separately supplied gases to form a non-homogeneous gas mixture; passing the non-homogeneous gas mixture into a static mixer or a buffer tank; conveying the gas mixture from the mixer or buffer tank into a compressor; compressing the gas mixture in the compressor; and withdrawing a substantially homogeneous compressed gas mixture from the compressor; wherein said gas mixture comprises at least one perfluorinated or partially fluorinated hydrocarbon or ether.

**[0007]** Preferably, the gas mixture further comprises at least one gas selected from the group consisting of SF<sub>6</sub> and inert gases, such as noble gases, CO<sub>2</sub> and N<sub>2</sub>.

**[0008]** In accordance with a further aspect, the objects are achieved by providing a mixing station for carrying out the foregoing method.

**[0009]** According to the invention, compounds selected from the group consisting of perfluorinated and/or partially fluorinated hydrocarbons are used as fluorinated hydrocarbons for the production of substantially homogeneous compressed gas mixtures from gases which are separately present.

**[0010]** Fluorinated compounds within the context of the invention are to be understood to mean perfluorinated and/or partially fluorinated hydrocarbons which can be pressure-liquefied, in particular those compounds which develop a vapour pressure of <30 bar (abs.) at 50°C. Suitable representatives of these classes of substances include, for example, R218 ( $C_3F_8$ ), R125 ( $CHF_2CF_3$ ), R227ea ( $CF_3CHFCF_3$ ), R134a ( $CH_2FCF_3$ ), R143a ( $CH_3CF_3$ ), R404 (R125/R143a/R134a), R23 ( $CHF_3$ ), R14 ( $CF_4$ ), R116 ( $CF_3CF_3$ ) or E125 ( $CF_3OCHF_2$ ). Suitable mixture constituents include, for example, SF<sub>6</sub>, inert gases, e.g. noble gases, CO<sub>2</sub> or N<sub>2</sub>.

**[0011]** The method provides for the gases which are supplied separately to be premixed, forming a non-homogeneous gas mixture, the non-homogeneous gas mixture to be passed into a static mixer and/or buffer tank, the gas mixture to be passed from the buffer tank or the static mixer into a compressor, and a substantially homogeneous compressed gas mixture to be delivered from the compressor, wherein, if a buffer tank is provided, a portion of the substantially homogeneous compressed gas mixture delivered from the compressor is returned into the buffer tank via a return line.

**[0012]** The method according to the invention makes it possible to produce homogeneously mixed gas mixtures at the point of use. It is therefore no longer necessary to supply gas mixtures homogeneously mixed ex works. Another advantage is that high flow rates (for example above 200 standard m<sup>3</sup> per hour) can be processed. In this case, the degree of mixing is independent of the cross-sections of the lines used. Metered delivery of the final homogeneous gas mixture is possible.

**[0013]** If a static mixer and a buffer tank are provided, it is advantageous to pass the gas first through the static mixer and then through the buffer tank.

**[0014]** In accordance with one preferred embodiment, the method is performed using a buffer tank, and a control valve is installed in the return line. The return of a portion of the gas mixture is adjusted to the desired

value with this control valve. This embodiment has the advantage that the compressor can be operated under gas ballast, and in addition the thorough mixing is improved still further. The control valve may, for example, be adjusted such that a predetermined proportion of the volume of the compressed gas delivered from the compressor is returned.

**[0015]** Advantageously, a safety means is provided which registers the fact that the filling limit has been reached in the electric cable which is to be filled or the gas cylinder which is to be filled, and switches off the compressor. This may, for example, be a pressure-relief valve, which from a predetermined pressure onwards opens and advantageously turns off the compressor. The pressure-relief line may be connected to the buffer tank. In this manner, the gas released through the pressure relief valve remains in circulation.

**[0016]** The compressor is adjusted such that it supplies a gas mixture having the desired pressure. The aforementioned gas mixtures are advantageously delivered at a pressure of 1 to 13 bar absolute. In particular, the pressure is in the range from 4 to 9 bar absolute.

**[0017]** Compressors which operate without oil, in particular diaphragm compressors, but also piston compressors, are advantageously used.

**[0018]** The quantities of gas which are supplied to form gas mixtures of given composition are preferably controlled via mass flow meters. This is advantageous precisely for gases with a high difference in density; the quantities of gas may be controlled accurately despite variable temperatures (influence of the time of day or year).

**[0019]** Preferably the method according to the invention can be used for the production of mixtures from gases in which at least one gas constituent is pressure-liquefied. Preferably  $\text{CHF}_2\text{CF}_3$ ,  $\text{CF}_3\text{CF}_3$ ,  $\text{C}_3\text{F}_8$ ,  $\text{CH}_2\text{FCF}_3$ ,  $\text{CH}_3\text{CF}_3$ ,  $\text{CF}_3\text{CHFCF}_3$  or  $\text{SF}_6$  are used as pressure-liquefiable gases.

**[0020]** The method is particularly well suited for producing homogeneous gas mixtures which contain or consist of  $\text{CF}_4$ ,  $\text{CHF}_2\text{CF}_3$ ,  $\text{CF}_3\text{CF}_3$ ,  $\text{C}_3\text{F}_8$

for feeding the gases to be mixed; a gas line for jointly passing on the premixed gases; a stationary mixer and/or a buffer tank into which the gas line for jointly passing on the premixed gases opens; a gas line which is connected to the buffer tank or stationary mixer and a compressor, through which gas mixture is passed from the buffer tank or the stationary mixer into the compressor; a compressor in which the gas mixture carried off from the buffer tank or stationary mixer is compressed and homogenised; a removal line for carrying the homogeneous compressed gas mixture out of the compressor. If a buffer tank is present, the mixing apparatus may also comprise a return line connected between the removal line from the compressor and the buffer tank, and a control valve in the return line. The feed lines for the gases to be mixed may be connected via a T-type connector to the gas line for jointly passing on the gases. One preferred embodiment of the mixing station has a buffer tank and a return line with control valve.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0027] The invention will be described in further detail hereinafter with reference to illustrative preferred embodiments depicted in the accompanying drawing figures, in which:

[0028] Figure 1 is a schematic illustration of a simple mixing station for carrying out the method of the invention, and

[0029] Figure 2 is a schematic diagram illustrating how the method of the invention is carried out.

#### DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0030] Figure 1 shows a simple mixing station which comprises two feed lines (1, 2); two valves (3, 4) for regulating the gas flow rate; a gas line (5) for passing on the premixed gases; a buffer tank (6); a compressor (7); a gas line (8) between the buffer tank (6) and the compressor (7); a removal line (9); a return line (10) between the buffer tank and the compressor; a control valve (11) in the return line; and a valve (12) for regulating the quantity of the homogeneous gas mixture removed.

**[0031]** The mixing station may comprise further useful components such as one or more manometers, pressure reducers, flow meters, pressure-relief valves, automatic shut-off means for the compressor, removal points for taking samples or a removal point for the homogeneous gas mixture. Particularly advantageously, the device comprises mass flow meters in order to regulate the quantities of gas. A collecting device of this type delivers accurate results independently of the temperature (time of day, time of year) at which it is operated - despite the high differences in gas density.

**[0032]** The mixing station may furthermore comprise: at least one holder for holding gas cylinders for one or more of the unmixed gases; a connection for connecting a gas cylinder for receiving the homogeneous compressed gas mixture; and/or at least one holder for such a gas cylinder.

**[0033]** It may furthermore comprise means for protecting from external influences. For example fittings with a tarpaulin may be provided, which keep dirt and the effects of the weather away from it.

**[0034]** The mixing station may be mobile. It then comprises the mixing station described above and an undercarriage on which the mixing station is mounted. For example, the undercarriage may be a truck or a trailer. This has the advantage that the mixing station can be moved along with the laying of underground cables to be insulated.

**[0035]** The method according to the invention will be explained in greater detail with reference to Fig. 2. The fluorinated hydrocarbons and nitrogen are introduced into a gas mixer (G) from the tank (ST) or the nitrogen tank (NT) via evaporators (V), manometers (M) and pressure reducers (D). The pressure between the manometer and the pressure reducer is 9 to 15 bar. In the gas mixer, the two gases are introduced into a common line (5) via mass flow meters and butterfly valves. The differential pressure between (M) and the static mixer (F) is at least 3 bar. The premixed gas is introduced into the buffer tank (6) via the static mixer (F) and is introduced from the buffer tank via line (8) into the compressor (7). A portion of the gas removed from the compressor via line (9) is returned

into the buffer tank via line (10) and the control valve (11). The pressure in the line (9) may range up to 13 bar (i.e. 14 bar absolute). Gas samples can be taken for analysis via the sampling points (13, 13') and (13''). The flow rate in line (9) is from 5 to 250 standard m<sup>3</sup> per hour. Homogeneous gas mixture is introduced into a gas cylinder, not shown here, via line (9). The control valve (11) is set such that the desired degree of thorough mixing is achieved - the greater the volume percent which is recycled to the buffer tank, the more ideal the thorough mixing, but of course also the lower the quantity of compressed gas mixture delivered. The compressed gas is delivered via the shut-off valve (14) to the article to be filled (e.g. an electric cable, switch housing or a gas cylinder).

**[0036]** The following examples are intended to illustrate the invention in further detail without limiting its scope.

## EXAMPLES

### Example 1:

The flow rates from the tank or the nitrogen tank were adjusted such that the volume ratio of C<sub>3</sub>F<sub>8</sub>:N<sub>2</sub> was exactly 40:60. Samples which were taken directly after the gas buffer tank and from the gas cylinder each had a content of 40% by volume C<sub>3</sub>F<sub>8</sub> and 60% by volume N<sub>2</sub>, and prove that optimum thorough mixing took place.

### Example 2:

The test was repeated, with a volume ratio of 50:50 being set. A sample taken after the buffer tank contained in each case 50% by volume of the mixture constituents.

Examples 3-7:

Ex.	Constituent 1	Constituent 2	Mixture ratio	Result
3	R125	SF <sub>6</sub>	80:20	Homogeneous gas mixture
4	R404A	SF <sub>6</sub>	80:20	Homogeneous gas mixture
5	R404A	N <sub>2</sub>	50:80	Homogeneous gas mixture
6	E125	SF <sub>6</sub>	70:30	Homogeneous gas mixture
7	R218	N <sub>2</sub>	20:80	Homogeneous gas mixture
8	R218	R125	20:80	Homogeneous gas mixture
9	R227	R125	50:50	Homogeneous gas mixture

In all the examples, it was possible to stay within the deviation of  $\pm 0.7\%$  by volume of the target mixture.

**[0037]** The foregoing description and examples have been set forth merely to illustrate the invention and are not intended to be limiting. Since modifications of the described embodiments incorporating the spirit and substance of the invention may occur to persons skilled in the art, the invention should be construed broadly to include all variations within the scope of the appended claims and equivalents thereof.